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Manjunath et al.

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(54) **DETECTING DEAUTHENTICATION AND DISASSOCIATION ATTACK IN WIRELESS LOCAL AREA NETWORKS**

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H04L 29/12 (2006.01)
(Continued)

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CPC ***H04L 63/1416*** (2013.01); ***H04L 61/6022*** (2013.01); ***H04W 12/12*** (2013.01); *H04W 8/26* (2013.01); *H04W 84/12* (2013.01)

(58) **Field of Classification Search**

CPC H04L 63/1416; H04L 61/6022; H04W 72/0453

See application file for complete search history.

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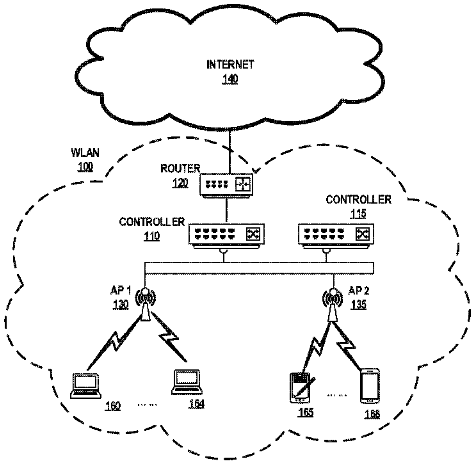
(74) *Attorney, Agent, or Firm* — Hewlett Packard Enterprise Patent Department

(57) **ABSTRACT**

The present disclosure relates to a network device that detects a deauthentication and/or disassociation attack in a wireless local area network (WLAN). In example implementations, the network device selects a random Media Access Control (MAC) address that is unused in the WLAN. The network device then transmits a request using the selected MAC address over a shared wireless communication channel. Next, the network device transmits a response using a MAC address corresponding to the network device over the shared wireless communication channel. Subsequently, the network device receives a disconnection request using the selected MAC address over the shared wireless communication channel. In response to receiving the disconnection request, the network device can detect an attacker device in the WLAN.

6 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

H04W 12/12	(2009.01)
H04W 84/12	(2009.01)
H04W 8/26	(2009.01)

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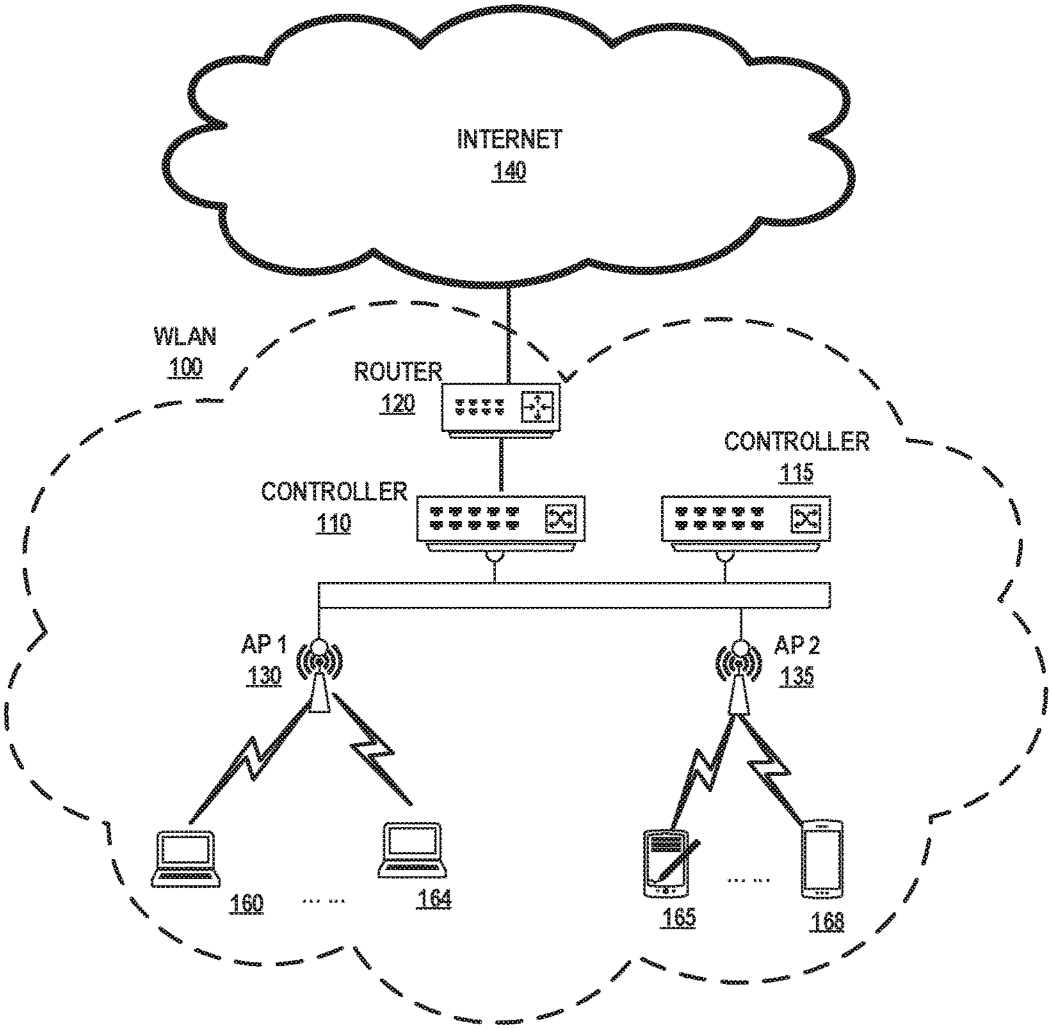
INTERNET
140
WLAN
100
ROUTER
120
CONTROLLER
115
CONTROLLER
110
AP 1
130
AP 2
135
160
… …
164
165
… …
168

FIG. 1

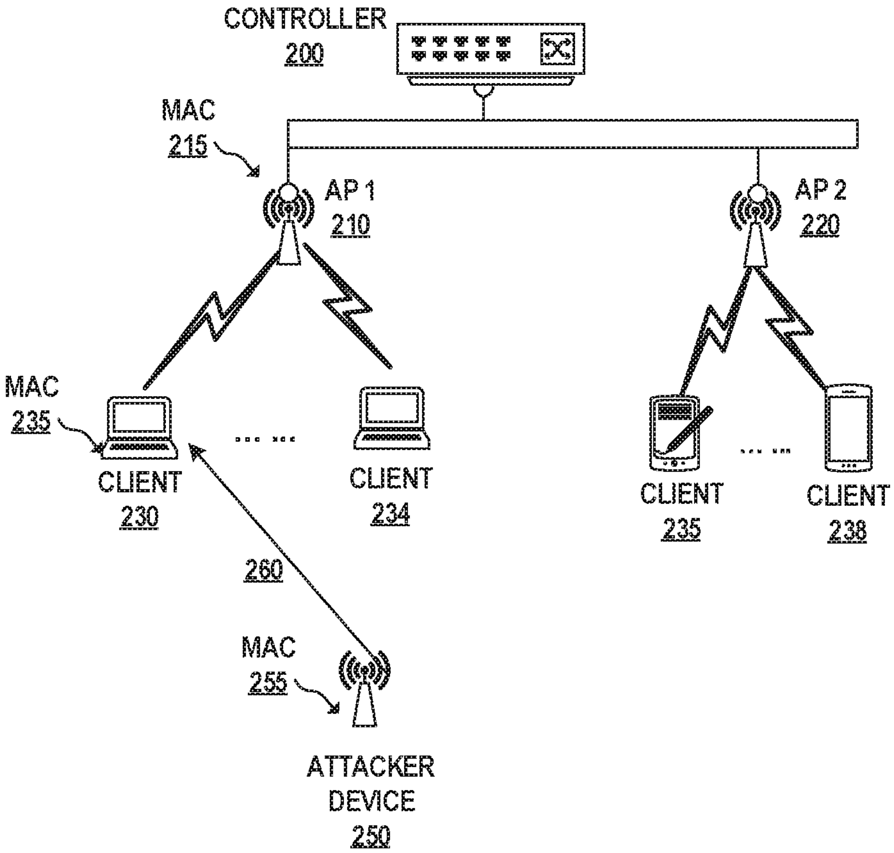
CONTROLLER
200
MAC
215
AP 1
210
AP 2
220
MAC
235
CLIENT
230
CLIENT
234
CLIENT
235
CLIENT
238
260
MAC
255
ATTACKER
DEVICE
250

FIG. 2

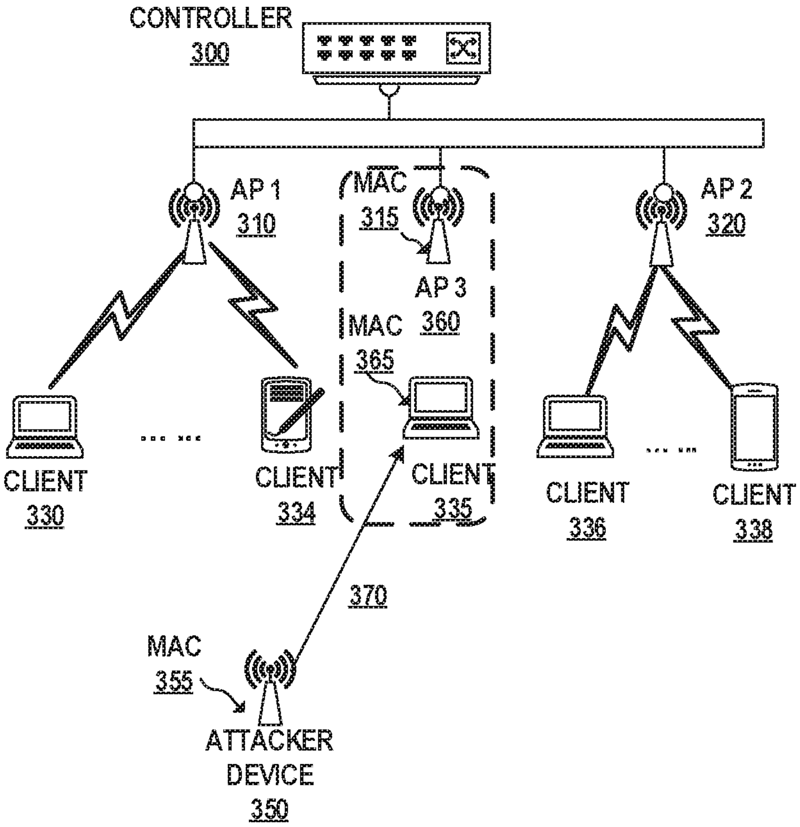
CONTROLLER
300
AP 1
310
MAC
315
AP 3
360
AP 2
320
MAC
365
CLIENT
330
CLIENT
334
CLIENT
335
CLIENT
336
CLIENT
338
370
MAC
355
ATTACKER
DEVICE
350

FIG. 3

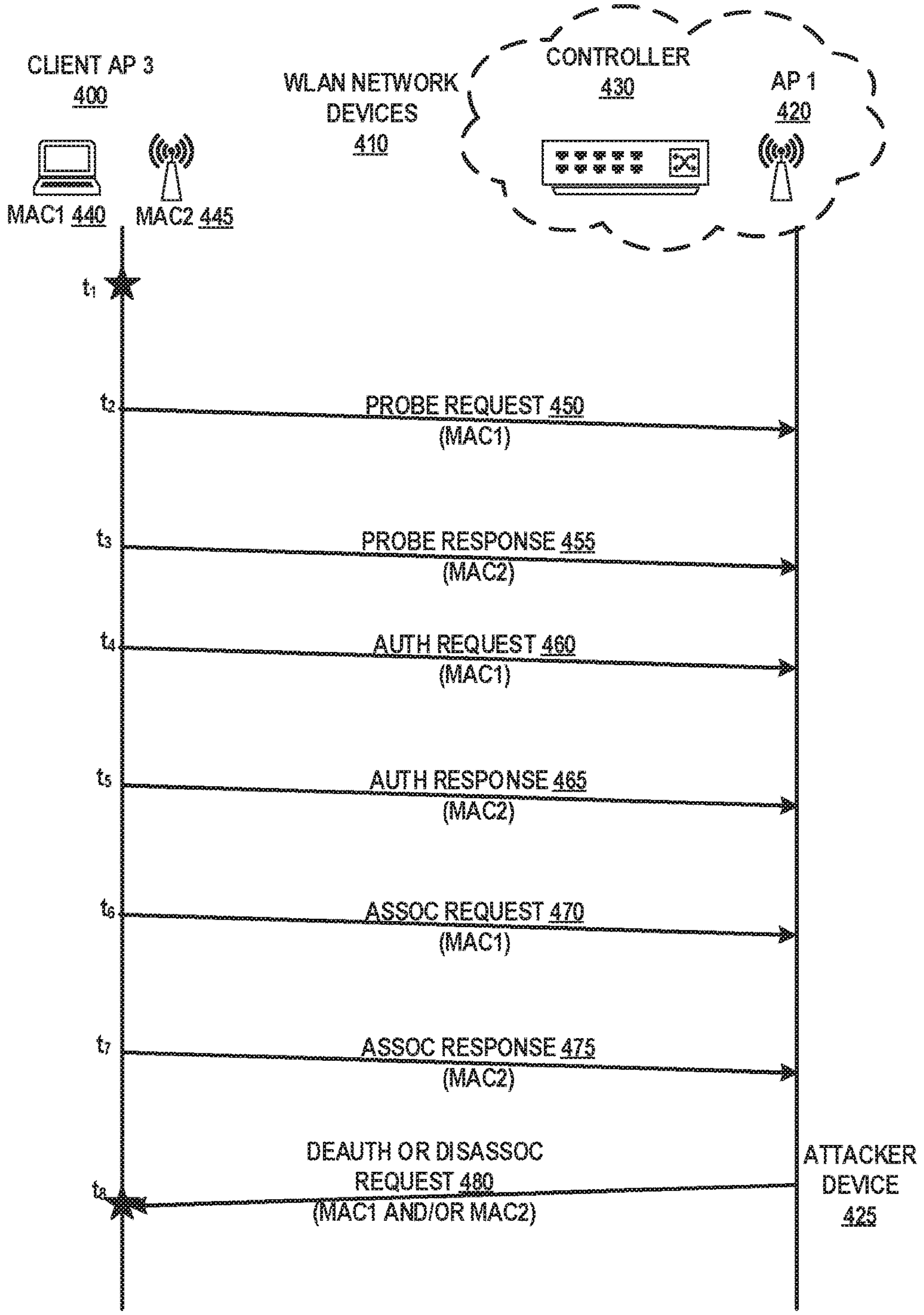
CLIENT AP 3
400
WLAN NETWORK DEVICES
410
CONTROLLER
430
AP 1
420
MAC1 440
MAC2 445
t1
t2
PROBE REQUEST 450
(MAC1)
t3
PROBE RESPONSE 455
(MAC2)
t4
AUTH REQUEST 460
(MAC1)
t5
AUTH RESPONSE 465
(MAC2)
t6
ASSOC REQUEST 470
(MAC1)
t7
ASSOC RESPONSE 475
(MAC2)
t8
DEAUTH OR DISASSOC REQUEST 480
(MAC1 AND/OR MAC2)
ATTACKER DEVICE
425

FIG. 4

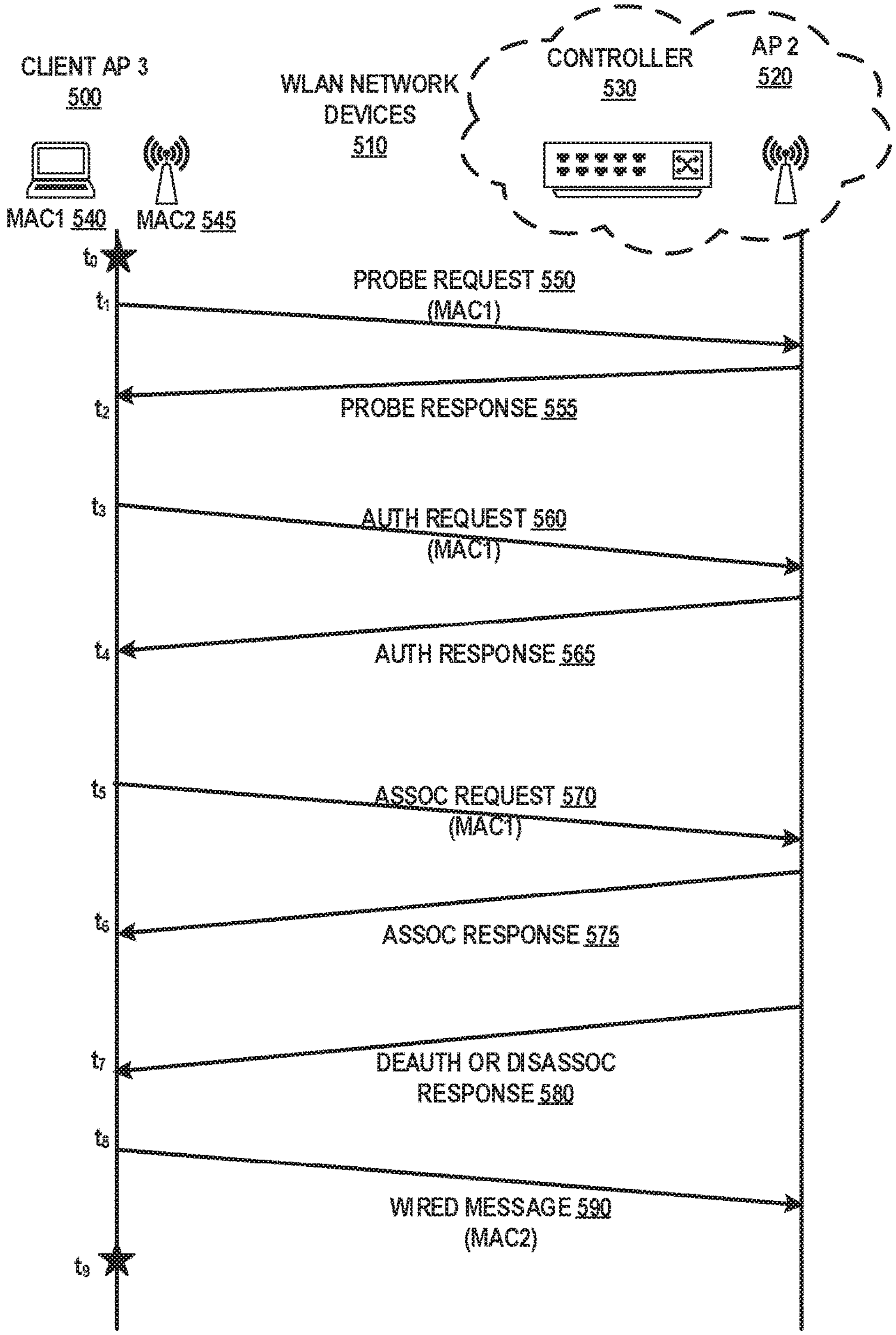
CLIENT AP 3
500
WLAN NETWORK
DEVICES
510
CONTROLLER
530
AP 2
520
MAC1 540
MAC2 545
t0
t1
PROBE REQUEST 550
(MAC1)
t2
PROBE RESPONSE 555
t3
AUTH REQUEST 560
(MAC1)
t4
AUTH RESPONSE 565
t5
ASSOC REQUEST 570
(MAC1)
t6
ASSOC RESPONSE 575
t7
DEAUTH OR DISASSOC
RESPONSE 580
t8
WIRED MESSAGE 590
(MAC2)
t9

FIG. 5

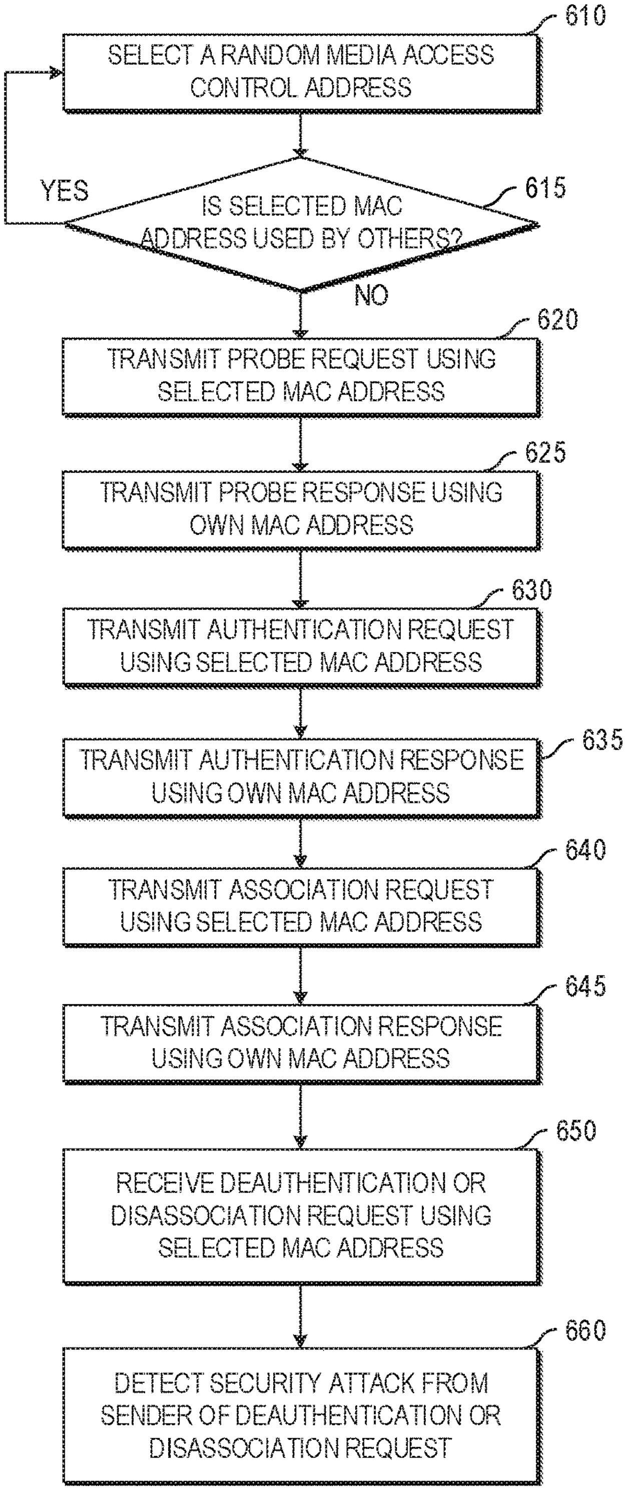
610
SELECT A RANDOM MEDIA ACCESS CONTROL ADDRESS
615
IS SELECTED MAC ADDRESS USED BY OTHERS?
YES
NO
620
TRANSMIT PROBE REQUEST USING SELECTED MAC ADDRESS
625
TRANSMIT PROBE RESPONSE USING OWN MAC ADDRESS
630
TRANSMIT AUTHENTICATION REQUEST USING SELECTED MAC ADDRESS
635
TRANSMIT AUTHENTICATION RESPONSE USING OWN MAC ADDRESS
640
TRANSMIT ASSOCIATION REQUEST USING SELECTED MAC ADDRESS
645
TRANSMIT ASSOCIATION RESPONSE USING OWN MAC ADDRESS
650
RECEIVE DEAUTHENTICATION OR DISASSOCIATION REQUEST USING SELECTED MAC ADDRESS
660
DETECT SECURITY ATTACK FROM SENDER OF DEAUTHENTICATION OR DISASSOCIATION REQUEST

FIG. 6

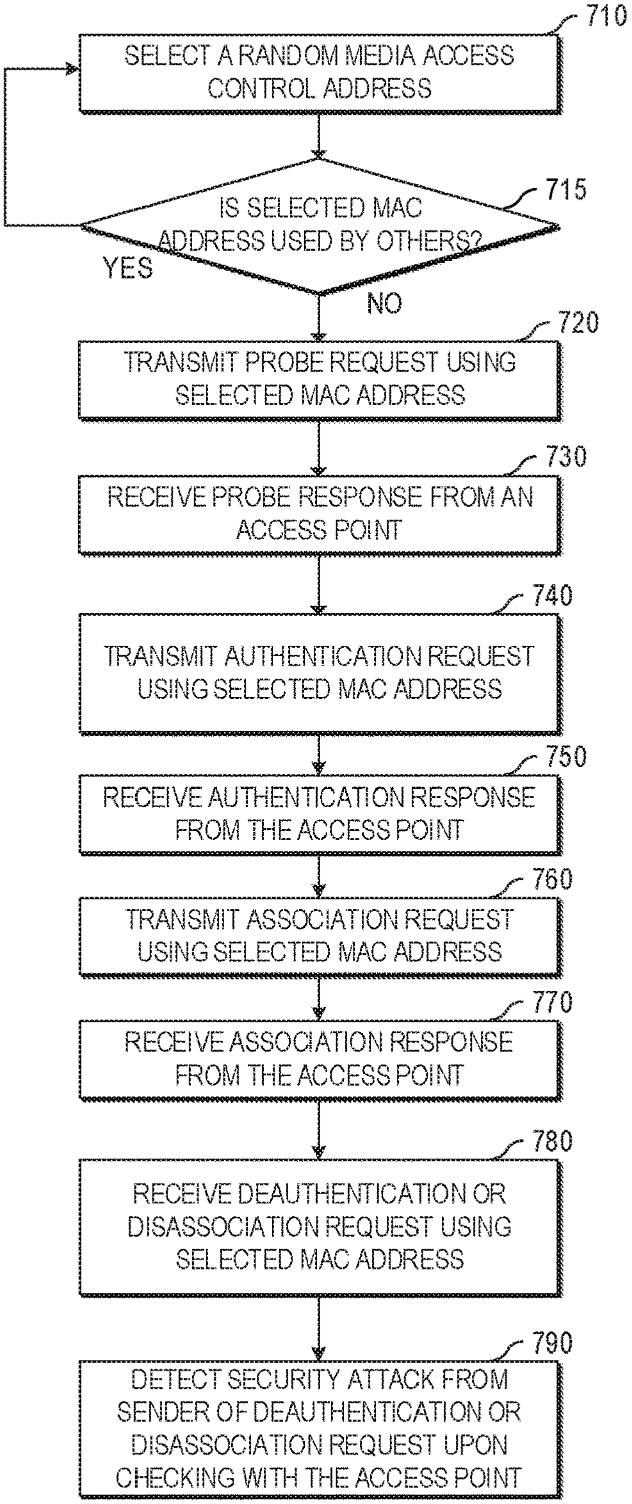
710
SELECT A RANDOM MEDIA ACCESS CONTROL ADDRESS
715
IS SELECTED MAC ADDRESS USED BY OTHERS?
YES
NO
720
TRANSMIT PROBE REQUEST USING SELECTED MAC ADDRESS
730
RECEIVE PROBE RESPONSE FROM AN ACCESS POINT
740
TRANSMIT AUTHENTICATION REQUEST USING SELECTED MAC ADDRESS
750
RECEIVE AUTHENTICATION RESPONSE FROM THE ACCESS POINT
760
TRANSMIT ASSOCIATION REQUEST USING SELECTED MAC ADDRESS
770
RECEIVE ASSOCIATION RESPONSE FROM THE ACCESS POINT
780
RECEIVE DEAUTHENTICATION OR DISASSOCIATION REQUEST USING SELECTED MAC ADDRESS
790
DETECT SECURITY ATTACK FROM SENDER OF DEAUTHENTICATION OR DISASSOCIATION REQUEST UPON CHECKING WITH THE ACCESS POINT

FIG. 7

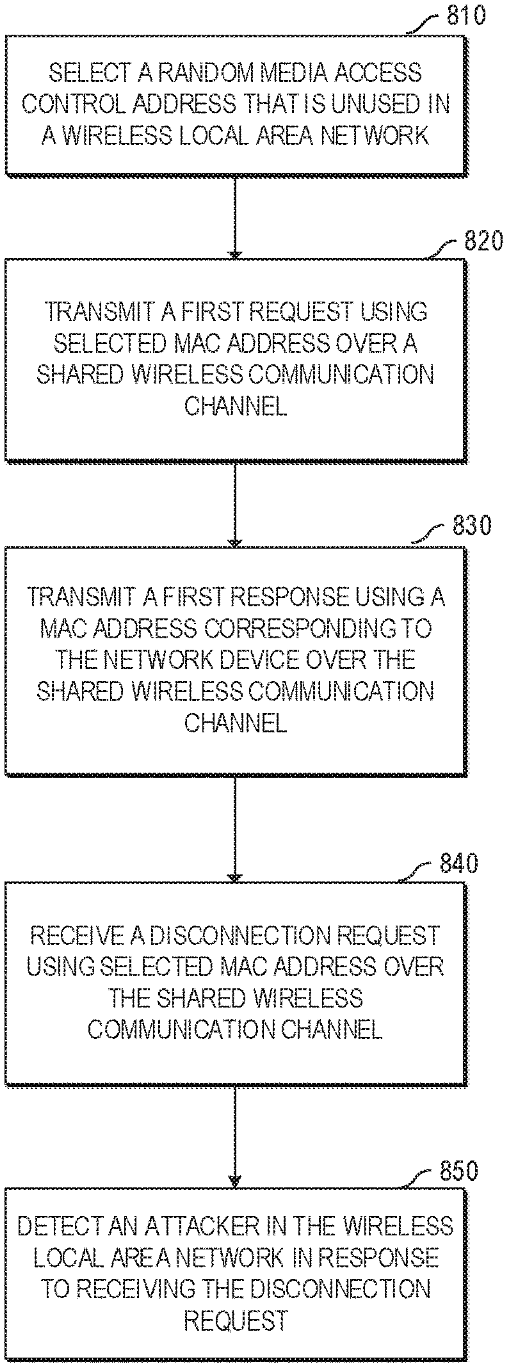
810
SELECT A RANDOM MEDIA ACCESS CONTROL ADDRESS THAT IS UNUSED IN A WIRELESS LOCAL AREA NETWORK
820
TRANSMIT A FIRST REQUEST USING SELECTED MAC ADDRESS OVER A SHARED WIRELESS COMMUNICATION CHANNEL
830
TRANSMIT A FIRST RESPONSE USING A MAC ADDRESS CORRESPONDING TO THE NETWORK DEVICE OVER THE SHARED WIRELESS COMMUNICATION CHANNEL
840
RECEIVE A DISCONNECTION REQUEST USING SELECTED MAC ADDRESS OVER THE SHARED WIRELESS COMMUNICATION CHANNEL
850
DETECT AN ATTACKER IN THE WIRELESS LOCAL AREA NETWORK IN RESPONSE TO RECEIVING THE DISCONNECTION REQUEST

FIG. 8

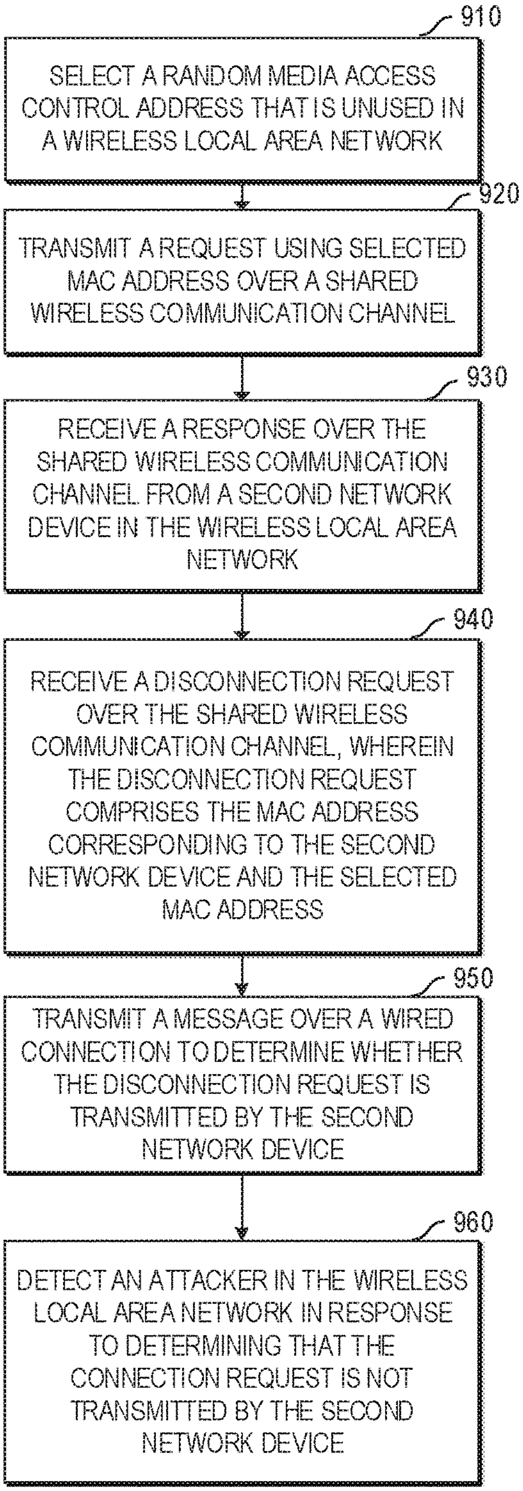
910
SELECT A RANDOM MEDIA ACCESS CONTROL ADDRESS THAT IS UNUSED IN A WIRELESS LOCAL AREA NETWORK
920
TRANSMIT A REQUEST USING SELECTED MAC ADDRESS OVER A SHARED WIRELESS COMMUNICATION CHANNEL
930
RECEIVE A RESPONSE OVER THE SHARED WIRELESS COMMUNICATION CHANNEL FROM A SECOND NETWORK DEVICE IN THE WIRELESS LOCAL AREA NETWORK
940
RECEIVE A DISCONNECTION REQUEST OVER THE SHARED WIRELESS COMMUNICATION CHANNEL, WHEREIN THE DISCONNECTION REQUEST COMPRISES THE MAC ADDRESS CORRESPONDING TO THE SECOND NETWORK DEVICE AND THE SELECTED MAC ADDRESS
950
TRANSMIT A MESSAGE OVER A WIRED CONNECTION TO DETERMINE WHETHER THE DISCONNECTION REQUEST IS TRANSMITTED BY THE SECOND NETWORK DEVICE
960
DETECT AN ATTACKER IN THE WIRELESS LOCAL AREA NETWORK IN RESPONSE TO DETERMINING THAT THE CONNECTION REQUEST IS NOT TRANSMITTED BY THE SECOND NETWORK DEVICE

FIG. 9

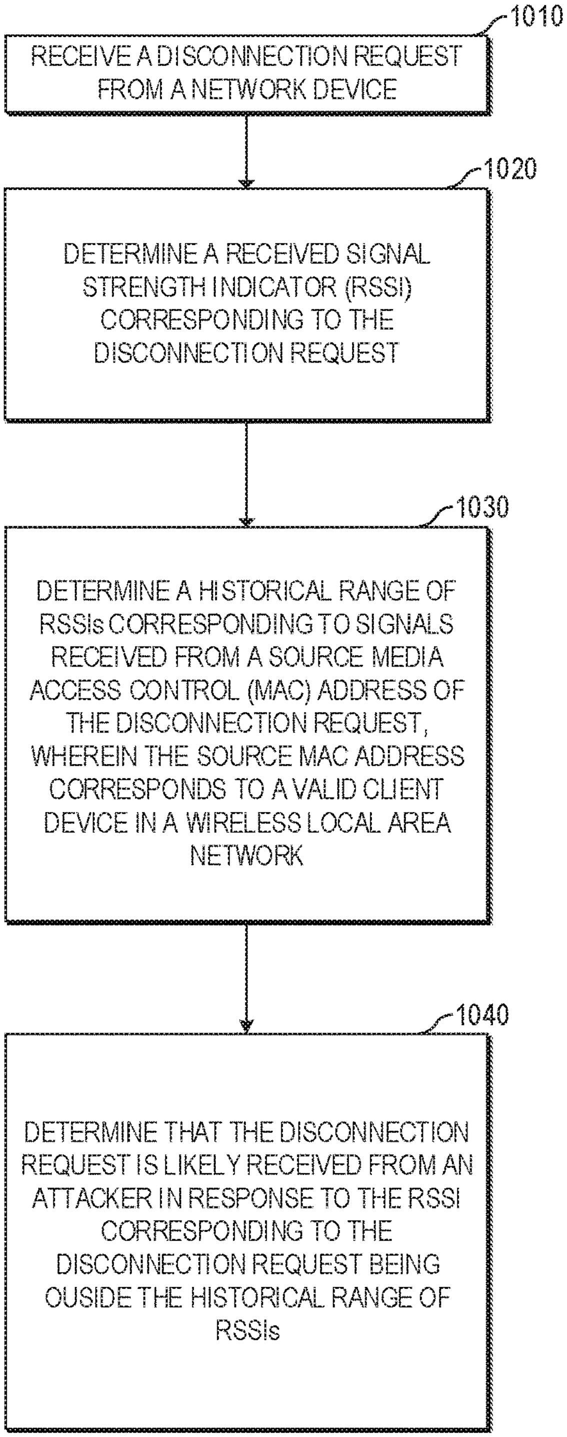
1010
RECEIVE A DISCONNECTION REQUEST FROM A NETWORK DEVICE
1020
DETERMINE A RECEIVED SIGNAL STRENGTH INDICATOR (RSSI) CORRESPONDING TO THE DISCONNECTION REQUEST
1030
DETERMINE A HISTORICAL RANGE OF RSSIs CORRESPONDING TO SIGNALS RECEIVED FROM A SOURCE MEDIA ACCESS CONTROL (MAC) ADDRESS OF THE DISCONNECTION REQUEST, WHEREIN THE SOURCE MAC ADDRESS CORRESPONDS TO A VALID CLIENT DEVICE IN A WIRELESS LOCAL AREA NETWORK
1040
DETERMINE THAT THE DISCONNECTION REQUEST IS LIKELY RECEIVED FROM AN ATTACKER IN RESPONSE TO THE RSSI CORRESPONDING TO THE DISCONNECTION REQUEST BEING OUSIDE THE HISTORICAL RANGE OF RSSIs

FIG. 10

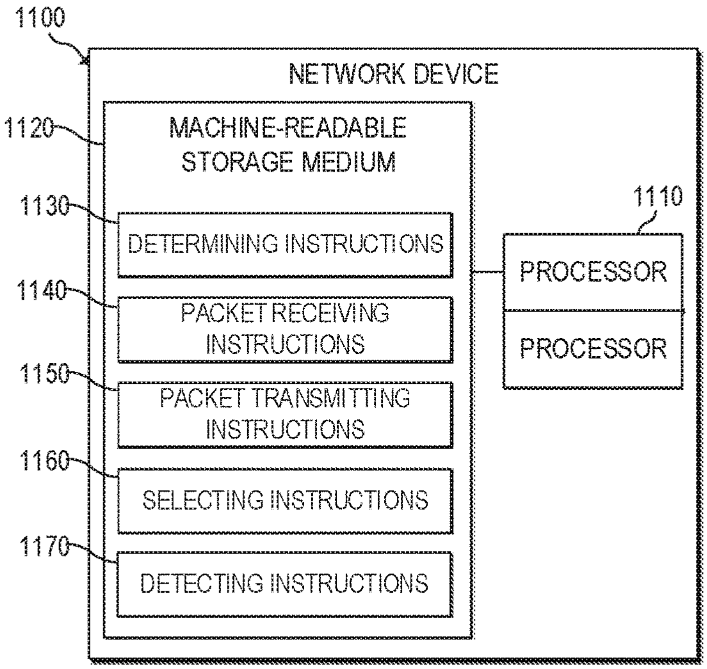
1100
NETWORK DEVICE
1120
MACHINE-READABLE STORAGE MEDIUM
1130
DETERMINING INSTRUCTIONS
1140
PACKET RECEIVING INSTRUCTIONS
1150
PACKET TRANSMITTING INSTRUCTIONS
1160
SELECTING INSTRUCTIONS
1170
DETECTING INSTRUCTIONS
1110
PROCESSOR
PROCESSOR

FIG. 11

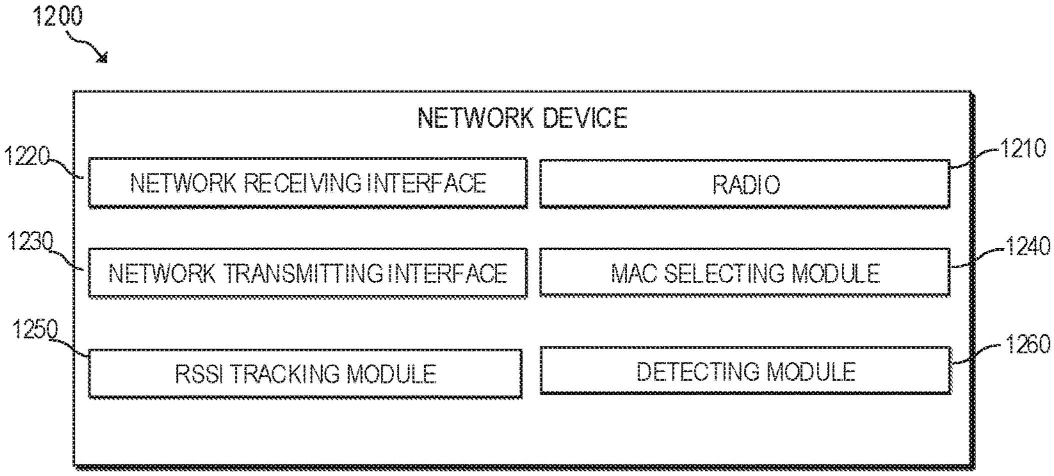
1200
NETWORK DEVICE
1220
NETWORK RECEIVING INTERFACE
RADIO
1210
1230
NETWORK TRANSMITTING INTERFACE
MAC SELECTING MODULE
1240
1250
RSSI TRACKING MODULE
DETECTING MODULE
1260

FIG. 12

DETECTING DEAUTHENTICATION AND DISASSOCIATION ATTACK IN WIRELESS LOCAL AREA NETWORKS

BACKGROUND

Since wireless local area network (WLAN) management frames are often unencrypted, an attacker can potentially attack the WLAN infrastructure by spoofing the Media Access Control (MAC) address of a client device that is associated with the WLAN, and sending a deauthentication and/or disassociation frame using the MAC address of the associated client device. Because the WLAN infrastructure cannot determine that the deauthentication and/or disassociation frame is from an attacker or a valid client device, it will terminate the client device's connection to the WLAN. As a result, a valid client device will experience denial of service by the WLAN infrastructure.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description references the drawings, wherein:

FIG. **1** is a block diagram of an example networking environment for a wireless local area network;

FIG. **2** is a block diagram of an example networking environment illustrating a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **3** is a block diagram of an example networking environment for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **4** is a sequence diagram of an example mechanism for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **5** is a sequence diagram of an example mechanism for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **6** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **7** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **8** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **9** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **10** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network;

FIG. **11** is a block diagram of an example network device for detecting a deauthentication and/or disassociation attack on the wireless local area network; and

FIG. **12** is a block diagram of an example network device for detecting a deauthentication and/or disassociation attack on the wireless local area network.

DETAILED DESCRIPTION

In the following description, several specific details are presented to provide a thorough understanding. While the context of the disclosure is directed to network security in wireless local area network, one skilled in the relevant art will recognize, however, that the concepts and techniques disclosed herein can be practiced without one or more of the

specific details, or in combination with other components, etc. In other instances, well-known implementations or operations are not shown or described in details to avoid obscuring aspects of various examples disclosed herein. As used herein, the term "implementation" generally refers an implementation that serves to illustrate by way of example but not limitation. It should be understood that this disclosure covers all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure.

Overview

The present disclosure relates to network security in a wireless local area network. In particular, the present disclosure relates to detecting a deauthentication and/or disassociation attack a wireless local area network (WLAN). Specifically, since WLAN management frames are often unencrypted, a security attacker to a WLAN infrastructure can spoof the MAC address of a client device that is associated with the WLAN, and send a deauthentication and/or disassociation packet to the access point (AP) that the client device is associated with.

Access Points (APs) in a WLAN typically honor the deauthentication and/or disassociation requests received from client devices. The APs will clean up client state internally upon receiving such requests from the client devices. Therefore, it is easy for a security attacker to sniff the WLAN infrastructure and to obtain the MAC addresses of associated client devices. The security attacker can then transmit a deauthentication and/or disassociation packet using each of the spoofed client MAC addresses. Because there is no way for the WLAN infrastructure to distinguish between a spoofed deauthentication and/or disassociation request and an authentic deauthentication and/or disassociation request, an AP will terminate the client association and treat the deauthentication and/or disassociation request as a valid request sent by the associated client device. Consequently, the originally associated client device will experience denied service by the AP, and be forced to reconnect to the WLAN to restore access. Also, with certain client driver implementations, the client devices can potentially blacklist the WLAN due to prior denied services.

With the solution provided herein, a network device selects a random Media Access Control (MAC) address that is unused in a wireless local area network (WLAN). The network device then transmits a first request using the selected MAC address over a shared wireless communication channel. Next, the network device trans response using a MAC address corresponding to the network device over the shared wireless communication channel. Subsequently, the network device receives a disconnection request using the selected MAC address over the shared wireless communication channel. Then, the network device detects an attacker in the WLAN in response to receiving the disconnection request.

In some implementations, instead of transmitting the first response using the MAC address corresponding to the network device, the network device receives a response over the shared wireless communication channel from a second network device (e.g., another access point) in the WLAN. Additionally, upon receiving a disconnection request, the network device will transmit a message over a wired connection to determine whether the disconnection request is indeed transmitted by the second network device. Thereafter, the network device detects an attacker in the WLAN if it determines that the connection request is not transmitted by the second network device.

Computing Environment

FIG. **1** shows an example networking environment for a wireless local area network. FIG. **1** includes a router **120** that connects to one or more network controllers (e.g., network controller **110** and network controller **115**) in a wireless local area network (WLAN) **100**. WLAN **100** is also connected to Internet **140**.

As used herein, "wireless local area network" (WLAN) generally refers to a communications network that links two or more devices using some wireless distribution mechanisms (for example, spread-spectrum or orthogonal frequency-division multiplexing radio). WLAN usually provides a connection through an access point to the Internet; and thus, providing users with the mobility to move around within a local coverage area and still stay connected to the network.

Network controller **110** and/or network controller **115** are communicatively coupled with one or more access points, such as AP**1** **130** and AP**2** **135**, to provide wireless network services to a number of wireless client devices, such as client devices **160-164** and client devices **165-168**.

As used herein, "access point" (AP) generally refers to receiving points for any known or convenient wireless access technology which may later become known. Specifically, the term AP is not intended to be limited to IEEE 802.11-based APs. An AP generally functions as an electronic device that is adapted to allow wireless devices to connect to a wired network via various communication standards.

Networks according to the present disclosure may operate on a private network including one or more local area networks. The local area networks may be adapted to allow wireless access, thereby operating as a wireless local area network (WLAN). In some implementations, the one or more local area networks may share the same extended service set (ESS) although each network corresponds to a unique basic service set (BSS) identifier.

In addition, network depicted in FIG. **1** may include multiple network control plane devices, such as network controllers, switches, or routers capable of controlling networking functions. Each network control plane device may be located in a separate sub-network. The network control plane device may manage one or more network management devices, such as access points or network servers, within the sub-network.

In some implementations, network controllers (e.g., network controller **110** and network controller **115**) support clustering and centralized management. For example, a master network controller can manage a number of local network controllers. The local network controllers collectively can support a large number of client devices (e.g., up to 32,000 client devices) in the WLAN at the same time.

For illustration purposes only, in the example network depicted in FIG. **1**, a number of client devices are connected to the access points in WLAN **100**. For example, client devices **160-164** are associated with AP**1** **130**, and client devices **165-168** are associated with AP**2** **135**. Note that client devices may be connected to the access points via either wired or wireless connections.

As used herein, the term "link" or "connection" (or used descriptively as "connected") is generally defined as a communication pathway established over an information-carrying medium. The "link" or "connection" may be a wired interconnect, wherein the medium is a physical medium (e.g., electrical wire, optical fiber, cable, bus traces, etc.), a wireless interconnect (e.g., air in combination with wireless signaling technology), or a combination of these technologies.

As used herein, "information" is generally defined as data, address, control, management (e.g., statistics) or any combination thereof. For transmission, information may be transmitted as a message, namely a collection of bits in a predetermined format. One type of message, namely a wireless message, includes a header and payload data having a predetermined number of bits of information. The wireless message may be placed in a format as one or more packets, frames, or cells.

Deauthentication and/or Disassociation Attack

FIG. **2** is a block diagram of an example networking environment illustrating a deauthentication and/or disassociation attack on a wireless local area network. Specifically, FIG. **2** includes at least a network controller **200** and a number of APs in the WLAN, such as AP**1** **210** and AP**2** **220**. In addition, a number of client devices are connected to the access points in the wireless local area network illustrated in FIG. **2**. For example, client devices **230-234** are associated with AP**1** **210**, and client devices **235-238** are associated with AP**2** **220**.

When a client device (e.g., client device **230**) connects to an access point (e.g., AP**1** **210**) in the WLAN, the client device and the AP perform certain communication exchanges over a shared wireless communication channel following a wireless communication protocol. For example, first, client device **230** may transmit a probe request message over the shared wireless communication channel to access points in the WLAN. The probe request is typically a broadcast message. Client device **230** may send a probe request message to each shared wireless communication channel over which client device **230** is capable of communicating.

Upon receiving the probe request message from client device **230**, an access point may respond with a probe response message over the shared wireless communication channel. Typically, the probe request message and the probe response message are not encrypted. Therefore, any wireless digital devices (e.g., wireless client devices or wireless access points) can receive the probe request message and/or the probe response message, and obtain information (e.g., source MAC address and/or destination MAC address) from those messages if they are capable of communicating over the same shared wireless communication channel.

It is possible that a plurality of access points in the WLAN respond to the probe request message from client device **230**. When client device **230** receive the probe response messages from one or more access points in the WLAN, client device **230** selects one particular access points (e.g., AP**1** **210**) to connect with. Then, client device **230** transmits an authentication request message to the selected AP (e.g., AP**1** **210**). Next, the selected AP (e.g., AP**1** **210**) will send an authentication response message to client device **230**. The authentication request message generally is a frame signifying to the network membership within the WLAN topology. The authentication function is handled by an exchange of management packets. Note that, in some implementations, the number of packets exchanged may depend on the authentication mechanism employed.

Next, upon successful authentication, client device **230** will send an association request message to the selected AP (e.g., AP**1** **210**). The association request message carries information about the network interface card (NIC) (e.g., supported data rates) and the service set identifier (SSID) of the wireless network that a client device wishes to associate with. The selected AP (e.g., AP**1** **210**) will then reply with an association response message to client device **230**. The association response message contains an acceptance or rejection notice to the radio NIC of the client device requesting association. If the selected AP (e.g., AP**1** **210**) accepts the association from client device **230**, the association response message includes information regarding the association, including but not limited to, the association ID and supported data rates. Also, the selected AP reserves memory space and establishes an association ID for the NIC.

In some implementations, when client device **230** roams away from an AP (e.g., AP**1** **210**) and attempts to associate with another AP (e.g., AP**2** **220**) in the WLAN, client device **230** may send a reassociation request message instead of the association request message. The reassociation request message is similar to the association request message, but is mainly useful in client roaming. For example, if client device **230** roams away from the currently associated access point (e.g., AP**1** **210**) and finds another access point (e.g., AP**2** **220**) having a stronger beacon signal, client device **230** will send a reassociation request message to the new access point (e.g., AP**2** **220**). The new access point (e.g., AP**2** **220**) then coordinates the forwarding of data frames that may still be in the buffer of the previous access point (e.g., AP**1** **210**) waiting for transmission to client device **230**.

Moreover, FIG. **2** also includes an attacker, Attacker Device **250**, to the WLAN infrastructure. Here, Attacker Device **250** can be an unauthorized access point or any unauthorized device that is deployed illegitimately within the coverage area of the WLAN. Note that Attacker Device **250** potentially can be run by any client device by injecting packets over a shared wireless network communication channel. For purpose of illustration, assuming that AP**1** **210** has a MAC address of MAC **215**; client device **230** has a MAC address of MAC **235**; and, Attacker Device **250** has a MAC address of MAC **255**. Further, Attacker Device **250** can be configured to switch its operating channel through each shared wireless communication channel in the WLAN and to listen for traffic on each shared wireless communication channel. Because none of the aforementioned communication exchanges between client device **230** and the selected AP (e.g., AP**1** **210**) is secured, Attacker Device **250** can sniff network packets on the shared wireless communication channel and receive all of the request and response messages transmitted between client device **230** and AP**1** **210**.

Therefore, Attacker Device **250** can obtain the MAC address of the associated client device (e.g., MAC **235** of client device **230**) and/or the MAC address of the selected AP (e.g., MAC **215** of AP**1** **210**). Subsequently, Attacker Device **250** can transmit a disconnection message **260** to break the connection between client device **230** and AP**1** **210**. For example, Attacker Device **250** can transmit a deauthentication message using MAC **215** of AP**1** **210** instead of its own MAC address (i.e., MAC **255** of Attacker Device **250**) as the source MAC address. Likewise, Attacker Device **250** can transmit a disassociation message using MAC **235** of client device **230** instead of its own MAC address (i.e. MAC **255** of Attacker Device **250**) as the source MAC address.

There is no way for an AP (e.g., AP**1** **210**) to determine whether a disassociation request message is from an authentic client device (e.g., client device **230**). Likewise, it is unlikely that a client device (e.g., client device **230**) can determine whether a deauthentication request message is from an authorized access point (e.g., AP**1** **210**). Generally, when an AP (e.g., AP**1** **210**) and/or client device (e.g., client device **230**) receives a deauthentication and/or disassociation message, the deauthentication/disassociation message is treated as if it was sent from a legitimate network device and/or client device. Therefore, the connection between AP**1** **210** and client device **230** will be terminated. AP**1** **210** will further clean up client state internally. This leads to the originally associated client device (e.g., client device **230**) being denied service by the AP (e.g., AP**1** **210**), forcing the client device (e.g., client device **230**) to reconnect to the WLAN in order to restore access.

Detecting Deauthentication/Disassociation Attack by Active Probing

FIG. **3** is a block diagram of an example networking environment for detecting a deauthentication and/or disassociation attack on the wireless local area network. Specifically, FIG. **3** includes at least a network controller **300** and a number of APs in the WLAN, such as AP**1** **310** and AP**2** **320**. In addition, a number of client devices are connected to the access points in the wireless local area network illustrated in FIG. **3**. For example, client devices **330**-**334** are associated with AP**1** **310**, and client devices **336**-**338** are associated with AP**2** **320**.

In addition, FIG. **3** includes an access point AP**3** **360** that emulates WLAN client behaviors. Like AP**1** **310** and AP**2** **320**, AP**3** **360** is connected to a number of client devices and is managed by network controller **300**. In particular, AP**3** **360** has a corresponding MAC address of MAC **315**. However, AP**3** **360** also can randomly select a MAC address (e.g., MAC **365**) that is different from its own MAC address (e.g., MAC **315**) and that is unused in the WLAN. Furthermore, AP**3** **360**, acting as client device **335**, can use the selected MAC address (e.g., MAC **365**) to transmit one or more requests over the shared wireless communication channel. When other network devices (e.g., controller **300**, AP**1** **310**, AP**2** **320**, etc.) receive the requests from AP**3** **360** over the shared wireless communication channel, they will treat the requests as being sent from client device **335**, even though client device **335** does not physically exist in the WLAN.

Moreover, FIG. **3** includes an attacker, Attacker Device **350**, to the WLAN infrastructure. Here, Attacker Device **350** is an unauthorized access point or any unauthorized device that is deployed illegitimately within the coverage area of the WLAN. Attacker Device **350** has a corresponding MAC address of MAC **355**. Further, Attacker Device **350** can be configured to listen for traffic on the shared wireless communication channel. When Attacker Device **350** hears certain communication exchanges between a client device and an AP over the shared wireless communication channel (e.g., a probe request, a probe response, an authentication request, an authentication response, an association/reassociation request, an association/reassociation response, etc.), Attacker Device **350** may determine that a connection has been successfully established between the client device and the AP. Therefore, Attacker Device **350** can obtain the MAC address of the associated client device and/or the MAC address of the AP. Subsequently, Attacker Device **350** can transmit a disconnection message **370** to break the connection between the client device and the AP using the associated client device's MAC address instead of its own MAC address (e.g., MAC **355**). The disconnection message may be a deauthentication message or a disassociation message.

There are at least two ways that an AP can detect the attacker Attacker Device **350** in the above scenario. First, the AP may act as a client device and an AP that serves the client device at the same time. Second the AP may collaborate with other authorized APs in the WLAN to detect the attacker.

A. Active Probing by Single Access Point

FIG. **4** is a sequence diagram of an example mechanism for detecting a deauthentication and/or disassociation attack on the wireless local area network. As used herein, the term "mechanism" generally refers to a component of a system or device to serve one or more functions, including but not limited to, software components, electronic components, electrical components, mechanical components, electro-mechanical components, etc.

Specifically, FIG. **4** includes an access point that can act as a client device (hereinafter referred to as "Client AP**3** **400**") and a number of WLAN network devices **410**. Further, WLAN network devices **410** may include a plurality of network controllers and/or access points, including but not limited to, controller **430** and AP**1** **420**. Network controller **430** manages the access points and client devices in the WLAN.

The access points in the WLAN may operate on one or more of shared wireless communication channels. They serve a number of wireless client devices by providing wireless network access to the client devices. Not all access points in WLAN network devices **410** are authorized by the WLAN. For example, an attacker may place an AP within the coverage area of WLAN to spoof communication exchanges between the client devices and authorized APs in the WLAN. Then, the attacker can use the spoofed information to start a deauthentication and/or disassociation attack. Unlike authorized APs in the WLAN, an AP from an attacker will not be able to connect to the network controllers and/or peer APs in the WLAN via a wired or otherwise secured connection.

In FIG. **4**, Client AP**3** **400** is communicatively coupled to WLAN network devices **410**. In particular, Client AP**3** **400** is connected to network controller **430** via a wired connection. When Client AP**3** **400** acts as an access point in the WLAN, Client AP**3** **400** uses its own MAC address, e.g., MAC**2** **445**. On the other hand, when Client AP**3** **400** acts as a client device in the WLAN, Client AP**3** **400** uses a randomly selected MAC address, e.g., MAC**1** **440**.

Specifically, at time point t_1, Client AP**3** **400** selects a random MAC address (e.g., MAC**1** **440**). The randomly selected MAC address (e.g., MAC**1** **440**) is different from Client AP**3** **400**'s own MAC address (e.g., MAC**2** **445**) and is unused by other client devices in the WLAN.

Thereafter, Client AP**3** **400** transmits a number of messages over a shared wireless communication channel in the WLAN. In particular, at time point t_2, Client AP**3** **400**, acting as a client device, transmits a probe request message **450** using MAC**1** **440** over the shared wireless communication channel. At time point t_3, Client AP**3** **400**, acting as an access point, transmits a probe response message **455** using MAC**2** **445** over the shared wireless communication channel. Next, at time point t_4, Client AP**3** **400**, acting as a client device, transmits an authentication request message **460** using MAC**1** **440** over the shared wireless communication channel. At time point t_5, Client AP**3** **400**, acting as an access point, transmits an authentication response message **465** using MAC**2** **445** over the shared wireless communication channel. Subsequently, at time point t_6, Client AP**3** **400**, acting as a client device, transmits an association request message **470** (or a reassociation request message) using MAC**1** **440** over the shared wireless communication channel. At time point t_7, Client AP**3** **400**, acting as an access point, transmits an association response message **475** (or a reassociation response message) using MAC**2** **445** over the shared wireless communication channel.

Because all of the above communication exchanges are transmitted over the shared wireless communication channel without any encryption, an unauthorized device, e.g., Attacker Device **425**, can sniff network packets on the shared wireless communication channel and receive all of the above messages, including probe request message **450**, probe response message **455**, authentication request message **460**, authentication response message **465**, association request message **470**, association response message **475**, etc. Therefore, upon the completion of the above communication exchanges, the unauthorized device (e.g., Attacker Device **425**) will determine that a connection has been successfully established between a client device with an MAC address of MAC**1** **440** and an access point with an MAC address of MAC**2** **445**.

In order to break the perceived connection between the client device and the access point, the unauthorized device (e.g., Attacker Device **425**) will transmit a deauthentication and/or disassociation request **480** using MAC**1** **440** and/or MAC**2** **445** that the unauthorized device (e.g., Attacker Device **425**) sniffed from the shared wireless communication channel.

At time point t_8, Client AP**3** **400** receives the deauthentication and/or disassociation request **480** from unauthorized Attacker Device **425** using MAC**1** **440** and/or MAC**2** **445**. Because Client AP**3** **400** does not send any deauthentication and/or disassociation request, Client AP**3** **400** can determine that the received deauthentication and/or disassociation request **480** is sent by an attacker to the WLAN infrastructure.

B. Active Probing by Collaborating Access Points

FIG. **5** is a sequence diagram of an example mechanism for detecting a deauthentication and/or disassociation attack on the wireless local area network. Specifically, FIG. **5** includes an access point that can act as a client device (hereinafter referred to as "Client AP**3** **500**") and a number of WLAN network devices **510**. Further, WLAN network devices **510** may include a plurality of network controllers and/or access points, including but not limited to, controller **530** and AP**2** **520**. Network controller **530** manages the access points and client devices in the WLAN.

The access points in the WLAN may operate on one or more of shared wireless communication channels. They serve a number of wireless client devices by providing wireless network access to the client devices. Moreover, the APs are connected to network controller **530** via wired connections. In addition, the APs in the WLAN can connect to the peer APs via wired connections too.

Not all access points in WLAN network devices **510** are authorized by the WLAN. For example, an attacker may place an AP within the coverage area of WLAN to spoof communication exchanges between the client devices and authorized APs in the WLAN. Then, the attacker can use the spoofed information to start a deauthentication and/or disassociation attack. Unlike authorized APs in the WLAN, an AP from an attacker will not be able to connect to the network controllers and/or peer APs in the WLAN via a wired or otherwise secured connection.

Client AP**3** **500** is communicatively coupled to WLAN network devices **510**. In particular, Client AP**3** **500** is connected to network controller **530** and/or a peer authorized AP, such as AP**2** **520**, via a wired connection. When Client AP**3** **500** acts as an access point in the WLAN, Client AP**3** **500** uses its own MAC address, e.g., MAC**2** **545**. On the other hand, when Client AP**3** **500** acts as a client device in the WLAN, Client AP**3** **500** uses a randomly selected MAC address, e.g., MAC**1** **540**.

Specifically, at time point t_0, Client AP**3** **500** selects a random MAC address MAC**1** **540**, The randomly selected MAC address is different from Client AP**3** **500**'s own MAC address (e.g., MAC**2** **545**) and is unused by other client devices in the WLAN.

Next, at time point t_1, Client AP**3** **500**, acting as a client device, transmits a probe request message **550** using MAC**1** **540** over the shared wireless communication channel. At time point t_2, Client AP**3** **400** receives a probe response message **555** from a peer AP (e.g., AP**2** **520**) in response to probe request message **550** over the shared wireless communication channel.

Thereafter, at time point t_3, Client AP**3** **500**, acting as a client device, transmits an authentication request message **560** using MAC**1** **540** over the shared wireless communication channel. At time point t_4, Client AP**3** **500** receives an authentication response message **565** from the peer AP (e.g., AP**2** **520**) over the shared wireless communication channel in response to authentication request message **560**.

Subsequently, at time point t_5, Client AP**3** **500**, acting as a client device, transmits an association request message **570** (or a reassociation request message) using MAC**1** **540** over the shared wireless communication channel. At time point t_6, Client AP**3** **500** receives an association response message **575** (or a reassociation response message) from the peer AP (e.g., AP**2** **520**) over the shared wireless communication channel in response to association request message **570** (or reassociation request message).

Because all of the above communication exchanges are transmitted over the shared wireless communication channel without any encryption, an unauthorized attacker device can sniff network packets on the shared wireless communication channel and receive all of the above messages, including probe request message **550**, probe response message **555**, authentication request message **560**, authentication response message **565**, association request message **570**, association response message **575**, etc. Therefore, upon the completion of the above communication exchanges, the unauthorized attacker device will determine that a connection has been successfully established between a client device with an MAC address of MAC**1** **540** and an access point with an MAC address of MAC**2** **545**.

In order to break the perceived connection between the client device and the access point, the unauthorized attacker device will transmit a deauthentication and/or disassociation request **580** using MAC**1** **540** and/or MAC**2** **545**, which the unauthorized attacker device sniffed from the shared wireless communication channel. At time point t_7, Client AP**3** **500** receives the deauthentication and/or disassociation request **580**.

In order to determine whether the received deauthentication and/or disassociation request **580** is from an unauthorized attacker device, at time point t_8, Client AP**3** **500** transmits a wired message **590** to network controller **530** and/or the peer AP (e.g., AP**2** **520**). Wired message **590** uses AP**3**'s MAC address (e.g., MAC**2** **545**) as the source MAC address. Also, wired message **590** serves as an inquiry to check whether a deauthentication and/or disassociation message has been sent.

In some implementations, Client AP**3** **500** can send the wired message to network controller **530**. Because network controller **530** provides centralized managements to the APs and client devices in the WLAN, network controller **530** can determine whether deauthentication and/or disassociation message **580** was sent by an authorized access point or client device.

In some implementations, Client AP**3** **500** can send the wired message to a peer AP (e.g., AP**2** **520**) that responded to the requests that Client AP**3** **500** sent out while acting as a client device. The peer AP can then notify Client AP**3** **500** whether it has sent deauthentication and/or disassociation message **580**.

If, at time point t_9, Client AP**3** detects that deauthentication and/or disassociation request **580** is not sent by an authorized client device or access point in the WLAN, Client AP**3** **450** can determine that deauthentication and/or disassociation request **580** is sent by an attacker device to the WLAN infrastructure.

Active probing by multiple collaborative access points allows the wireless local area network to perform the active probing over a wider coverage area. For example, with a single access point, the mechanisms described herein will be able to detect deauthentication and/or disassociation attackers within the radio frequency neighborhood of an individual access point. However, by collaborating with multiple access points, the mechanisms described above can potentially detect attackers over a much larger coverage area, e.g., the combined coverage area provided by multiple access points in the WLAN.

Process to Detect Deauthentication and/or Disassociation Attack

FIG. **6** is a flowchart of example process for detecting a deauthentication and/or disassociation attack on the wireless local area network. In this example, a network device begins the process by selecting a random Media Access Control (MAC) address (operation **610**). Then, the network device determines whether the selected MAC address is used by other devices (operation **615**). If so, the network device repeats the previous operation and selects another random MAC address (operation **610**).

If the selected MAC address is unused by other devices in the WLAN, the network device proceeds to transmit a probe request using the selected MAC address (operation **620**). Next, the network device transmits a probe response using its own MAC address (operation **625**). Then, the network device transmits an authentication request using selected MAC address (operation **630**). Thereafter, the network device transmits an authentication response using its own MAC address (operation **635**). Moreover, the network device transmits an association (or reassociation) request using the selected MAC address (operation **640**). Subsequently, the network device transmits an association (or reassociation) response using its own MAC address (operation **645**).

Note that the probe request, the probe response, the authentication request, the authentication response, the association (or reassociation) request, and the association (or reassociation) response are all transmitted on a shared wireless communication channel without encryption. Therefore, an attacking network device may be configured to operate on the shared wireless communication channel and observe all of the above communication exchanges. Based on the observed communication exchanges, the attacking network device will determine that a wireless connection has been established successfully between a client device with the selected MAC address and an access point with the network device's own MAC address. In order to attack this perceived wireless connection between the client device and the access point, the attacking network device can transmit a deauthentication request and/or a disassociation request using the selected MAC address.

As a result, the network device will receive a deauthentication and/or a disassociation request using the selected

MAC address (operation **650**). The network device is aware that the selected MAC address is used to emulate a client device and there is no wireless connection established between an actual client device and the network device. Therefore, the network device can detect a security attack from the sender of the deauthentication and/or disassociation request (operation **660**).

FIG. **7** is a flowchart of another example process for detecting a deauthentication and/or disassociation attack on the wireless local area network. In this example, the network device collaborates with another network device (e.g., another access point) in the WLAN to detect a deauthentication and/or disassociation attack. First, the network device begins the process by selecting a random Media Access Control (MAC) address (operation **710**). Then, the network device determines whether the selected MAC address is used by other devices (operation **715**). If so, the network device repeats the previous operation and selects another random MAC address (operation **710**).

If the selected MAC address is unused by other devices in the WLAN, the network device proceeds to transmit a probe request using the selected MAC address (operation **720**). Next, the network device receives a probe response from an access point in the WLAN (operation **730**). Then, the network device transmits an authentication request using the selected MAC address (operation **740**). Thereafter, the network device receives an authentication response from the access point (operation **750**). Moreover, the network device transmits an association (or reassociation) request using the selected MAC address (operation **760**). Subsequently, the network device receives an association (or reassociation) response from the access point (operation **770**).

Here, again, the probe request, the probe response, the authentication request, the authentication response, the association (or reassociation) request, and the association (or reassociation) response are all transmitted on a shared wireless communication channel without encryption. Therefore, an attacking network device may be configured to operate on the shared wireless communication channel and observe all of the above communication exchanges. Based on the observed communication exchanges, the attacking network device will determine that a wireless connection has been established successfully between a client device with the selected MAC address and the access point in the WLAN that sent the responses. In order to attack this perceived connection between the client device and the access point, the attacking network device can transmit a deauthentication and/or a disassociation request using the selected MAC address.

As a result, the network device will receive a deauthentication and/or a disassociation request using the selected MAC address (operation **780**). Here, the network device is aware that the selected MAC address is used to emulate a client device. However, unlike in the previous example, the network device cannot determine, based on the received deauthentication/disassociation request alone, whether the sender of the deauthentication/disassociation request is an attacker. Therefore, the network device will inquire the access point and detect a security attack from the sender of the deauthentication and/or disassociation request upon checking with the access point (operation **790**).

Specifically, the network device can send a message via a wired or otherwise secured connection to the access point or to a network controller managing the access point and its associated client devices. The message may include an inquiry to determine whether the access point has transmitted a deauthentication and/or disassociation request to a client device having the selected MAC address. Because the wired connection is typically a secured connection that is only accessible to provisioned and authorized network devices. The attacking network device operating on the shared wireless communication channel will not receive the wired message. As a result, if the deauthentication and/or disassociation request is sent by the attacking network device, the network device would not receive a reply to the message, which was sent via the wired connection. Therefore, the network device can detect the security attack from the sender of the deauthentication and/or disassociation request based on the absence of reply to its inquiry message sent over the wired connection.

FIG. **8** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network. In this example, a network device first selects a random Media Access Control (MAC) address that is unused in a wireless local area network (WLAN) (operation **810**). Then, the network device transmits a first request using the selected MAC address over a shared wireless communication channel (operation **820**). Next, the network device transmits a first response using a MAC address corresponding to the network device over the shared wireless communication channel (operation **830**). Subsequently, the network device receives a disconnection request using the selected MAC address over the shared wireless communication channel (operation **840**). Thereafter, the network device detects an attacker in the wireless local area network in response to receiving the disconnection request (operation **850**).

Here, the first request may include one or more of a probe request, an authentication request, an association request, and a reassociation request. Moreover, the first response may include one or more of a probe response, an authentication response, an association response, and a reassociation response. Furthermore, the disconnection request may include one or more of a de-authentication request and a disassociation request.

In some implementations, the network device involves an access point. Also, the selected MAC address is used to emulate a client device in the wireless local area network; and the shared wireless communication channel is accessible to the attacker.

In some implementations, the network device further determines a received signal strength indicator (RSSI) corresponding to the disconnection message received by the network device. In addition, the network device determines a plurality of RSSIs associated with signals corresponding to the disconnection message received by other access points in the wireless local area network. Further, the network device can locate the attacker through triangulation based on the RSSI corresponding received by the network device and the plurality of RSSIs corresponding to signals received by the other access points.

In some implementations, the network device further transmits a second request using the selected MAC address over the shared wireless communication channel. Also, the network device transmits a second response using the MAC address corresponding to the network device over the shared wireless communication channel. Here, the first request includes a probe request; the first response includes a probe response; the second request includes an authentication request; and, the second response includes an authentication response.

In some implementations, the network device further transmits a third request using the selected MAC address over the shared wireless communication channel. Moreover, the network device can transmit a third response using the MAC address corresponding to the network device over the shared wireless communication channel. Here, the third request includes an association (or reassociation) request; and, the third response includes an association (or reassociation) response.

FIG. **9** is a flowchart of example process for detecting a deauthentication and/or disassociation attack on the wireless local area network. In this example, a network device first selects a random Media Access Control (MAC) address that is unused in a wireless local area network (operation **910**). The selected MAC address is used to emulate a client device in the wireless local area network. The network device then transmits a request using the selected MAC address over a shared wireless communication channel (operation **920**). Next, the network device receives a response over the shared wireless communication channel from a second network device in the wireless local area network (operation **930**). Subsequently, the network device receives a disconnection request over the shared wireless communication channel, wherein the disconnection request includes the MAC address corresponding to the second network device and the selected MAC address (operation **940**). Then, the network device transmits a secure message over a wired connection to determine whether the disconnection request is transmitted by the second network device (operation **950**). Further, the network device will detect an attacker in the wireless local area network in response to determining that the connection request is not transmitted by the second network device (operation **960**). Here, the first network device and the second network device are access points in the wireless local area network. Moreover, the message over the wired connection can be transmitted to the second network device (e.g., another access point), a network controller, or a master network controller in a controller cluster that manages client devices and access points in the wireless local area network.

In some implementations, the first request may include a probe request, an authentication request, an association request, and/or a reassociation request. The first response may include a probe response, an authentication response, an association response, and/or a reassociation response. Furthermore, the disconnection request may include a deauthentication request and/or a disassociation request.

Detecting Deauthentication/Disassociation Attack by RSSI Monitoring

FIG. **10** is a flowchart of an example process for detecting a deauthentication and/or disassociation attack on the wireless local area network. In this example, a network device receives a disconnection request from another network device (operation **1010**). The disclosed network device then determines a received signal strength indicator (RSSI) corresponding to the disconnection request (operation **1020**). Next, the disclosed network device determines a historical range of RSSIs corresponding to the signals received from a source MAC address of the disconnection request (operation **1030**). Here, assuming that the source MAC address corresponds to a valid client device in a wireless local area network.

Then, the disclosed network device can determine that the disconnection request is likely received from an attacker in response to the RSSI corresponding to the disconnection request being outside the historical range of the RSSIs (operation **1040**). This is because an RSSI outside the historical range of RSSIs corresponding to signals received from a client device generally indicate that the client device has a different transmitting power or is at a different location than its usual location. Therefore, the sender of the disconnection request is a potential attacker.

In some implementations, the network device detects an attack if the difference between the RSSI corresponding to the disconnection request and the maximal or minimal value of the historical range exceeds a predetermined threshold value.

In some implementations, the disclosed network device further ignores the disconnection request. Then, the disclosed network device determines whether a plurality of disconnection requests are subsequently received from the network device. In response to the plurality of disconnection requests being subsequently received from the network device, the disclosed network device determines that the network device is an attacker in the wireless local area network. Note that the disconnection request may include, but is not limited to, a de-authentication request and/or a disassociation request.

Machine Readable Storage Medium to Detect Deauthentication and/or Disassociation Attack

The present disclosure also may be embedded in a non-transitory computer-readable storage medium (e.g., a programmable circuit; a semiconductor memory such as a volatile memory such as random access memory "RAM," or non-volatile memory, such as read-only memory, power-backed RAM, flash memory, phase-change memory or the like; a hard disk drive; an optical disc drive; or any connector for receiving a portable memory device such as a Universal Serial Bus "USB" flash drive), which comprises all the features enabling the implementation of the methods described herein, and which when loaded in a computer system is able to carry out these methods. Computer program in the present context means any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following: a) conversion to another language, code or notation; b) reproduction in a different material form.

FIG. **11** is a block diagram of an example network device for detecting a deauthentication and/or disassociation attack on the wireless local area network. Network device **1100** generally includes a device suitable for transmitting and/or receiving network signals and for processing information within such network signals in order to provide network services to client devices, such as, an access point, a network switch, a router, a network controller, a server, a network data center, etc. As illustrated in FIG. **11**, network device **1100** includes one or more processors **1110** and a machine-readable storage medium **1120**.

Processor **1110** may be one or more central processing units (CPUs), CPU cores, semiconductor-based microprocessors, and/or other hardware devices suitable for retrieval and execution of instructions stored in machine-readable storage medium **1120**. Processor **1110** may fetch, decode, and execute instructions **1130**, **1140**, **1150**, **1160**, and **1170** to control the process for detecting a deauthentication and/or disassociation attack. As an alternative or in addition to retrieving and executing instructions, processor **1110** may include one or more electronic circuits that include electronic components for performing the functionality of one or more of instructions **1130**, **1140**, **1150**, **1160**, and **1170**.

Machine-readable storage medium **1120** may be any electronic, magnetic, optical, or other physical storage device that contains or stores executable instructions. Thus, machine-readable storage medium **1120** may be, for example, Random Access Memory (RAM), an Electrically

Erasable Programmable Read-Only Memory (EEPROM), a storage device, an optical disc, and the like. In some implementations, machine-readable storage medium **1120** may be a non-transitory storage medium, where the term "non-transitory" does not encompass transitory propagating signals. As described in details below, non-transitory machine-readable storage medium **1120** may be encoded with a series of executable instructions **1130**, **1140**, **1150**, **1160**, and **1170** for determining various parameters, network status, and so on; for receiving and transmitting network packets; for selecting MAC addresses; for detecting a security attack; etc.

Specifically, determining instructions **1130** include instructions to determine a received signal strength indicator (RSSI) corresponding to the disconnection message received by network device **1100**. Further, determining instructions **1130** include instructions to determine a plurality of RSSIs associated with signals corresponding to the disconnection message received by other access points in the wireless local area network, and to locate an attacker based on the RSSI corresponding to the signal received by the network device and the plurality of RSSIs corresponding to the signals received by the other access points.

In some implementations, determining instructions **1130** include instructions to determine a historical range of RSSIs corresponding to signals received from a source Media Access Control (MAC) address of the disconnection request. Here, the source MAC address corresponds to a valid client device in a wireless local area network. In response to the RSSI corresponding to the disconnection request being outside the historical range of RSSIs, determining instructions **1130** also include instructions to determine that the disconnection request is likely received from an attacker.

In some implementations, whereas packet receiving instructions **1140** instruct one or more processors **1110** to ignore the disconnection request, determining instructions **1130** include instructions to determine whether a plurality of disconnection requests are subsequently received from another network device. In response to the plurality of disconnection requests being subsequently received from the other network device, determining instructions **1130** include instructions to determine that the other network device is an attacker in the wireless local area network.

Packet receiving instructions **1140** generally include instructions to receive packets from the network. In particular, packet receiving instructions **1140** include instructions to receive a response over a shared wireless communication channel from a second network device in the wireless local area network. Also, packet receiving instructions **1140** include instructions to receive a disconnection request using the selected MAC address over the shared wireless communication channel. In some implementations, packet receiving instructions **1140** include instructions to ignore the received disconnection request.

Packet transmitting instructions **1150** generally include instructions to transmit a message to the network over a shared wireless communication channel and/or via a wired connection. Specifically, packet transmitting instructions **1150** include instructions to transmit a first request using the selected MAC address over a shared wireless communication channel; to transmit a first response using a MAC address corresponding to the network device over the shared wireless communication channel; to transmit a second request using the selected MAC address over the shared wireless communication channel; to transmit a second response using the MAC address corresponding to the network device over the shared wireless communication channel; to transmit a third request using the selected MAC address over the shared wireless communication channel; to transmit a third response using the MAC address corresponding to the network device over the shared wireless communication channel; etc.

In one example implementation, the first request comprises a probe request message; the first response comprises a probe response message; the second request comprises an authentication request message; the second response comprises an authentication response message; the third request comprises an association (or reassociation) request message; and, the third response comprises an association (or reassociation) response message.

In some implementations, packet transmitting instructions **1150** also include instructions to transmit a message over a wired connection to determine whether the disconnection request is transmitted by the second network device.

Selecting instructions **1160** generally include instructions to select a random Media Access Control (MAC) address that is unused in a wireless local area network. Specifically, the selected MAC address can be used to emulate a client device in the wireless local area network.

Detecting instructions **1170** generally include instructions to detect an attacker in the wireless local area network in response to receiving the disconnection request. Specifically, detecting instructions **1170** include instructions to detect an attacker in the wireless local area network in response to determining that the disconnection request is not transmitted by another authorized network devices in the WLAN.

Network Device to Detect Deauthentication/Disassociation Attack

FIG. **12** is a block diagram of an example network device for detecting a deauthentication and/or disassociation attack on the wireless local area network. As with network device **1100** of FIG. **11**, network device **1200** may be any electronic device suitable for transmitting and/or receiving network signals and for processing information within such network signals in order to provide network services to client devices, such as, an access point, a network switch, a router, a network controller, a server, a network data center, etc. As illustrated in FIG. **12**, network device **1200** includes at least a radio **1210**, a network receiving interface **1220**, a network transmitting interface **1230**, a MAC selecting module **1240**, a RSSI tracking module **1250**, a detecting module **1260**, etc.

In particular, radio **1210** may be any combination of known or conventional electrical components for receipt of signaling, including but not limited to, transistors, capacitors, resistors, multiplexers, wiring, registers, diodes or any other electrical components known or later become known.

Network receiving interface **1220** typically is responsible for receiving network messages and/or packets, including but not limited to a probe request, a probe response, an authentication request, an authentication response, an association request, an association response, a reassociation request, a reassociation response, a deauthentication request, a disassociation request, etc.

Network transmitting interface **1230** typically is responsible for transmitting network messages and/or packets, including but not limited to, a probe request, a probe response, an authentication request, an authentication response, an association request, an association response, a reassociation request, a reassociation response, a deauthentication request, a disassociation request, etc.

MAC selecting module **1240** typically is responsible for selecting a random MAC address. The selected MAC address is unused by other devices in the WLAN and is used to emulate a client device by a network device.

RSSI tracking module **1250** typically tracks the received signal strength indicators (RSSIs) corresponding to signals received from client devices by the APs in the WLAN.

Detecting module **1260** typically detects an attacker in the WLAN. Specifically, detecting module **1260** is responsible for detecting a deauthentication and/or disassociation attack.

The foregoing disclosure describes a number of example implementations for improved network security in a wireless local area network. As detailed above, example implementations provide an intuitive, discoverable mechanism for detecting a deauthentication and/or disassociation attack in a WLAN. Additional implementations and advantages of such implementations will be apparent to those of skill in the art upon reading and understanding the foregoing description.

We claim:

1. A first network device comprising:

a memory;

one or more processors to:

select a random Media Access Control (MAC) address that is unused in a wireless local area network;

transmit a request using the selected MAC address over a shared wireless communication channel;

receive a response over the shared wireless communication channel from a second network device in the wireless local area network;

receive a disconnection request over the shared wireless communication channel, wherein the disconnection request comprises the MAC address corresponding to the second network device and the selected MAC address;

transmit a message over a wired connection to determine whether the disconnection request is transmitted by the second network device; and

detect an attacker in the wireless local area network in response to determining that the disconnection request is not transmitted by the second network device.

2. The network device of claim **1**, wherein the message over the wired connection is transmitted to at least one of the second network device and a network controller that manages client devices and access points in the wireless local area network.

3. The network device of claim **1**, wherein the first request comprises one or more of a probe request, an authentication request, and an association request.

4. The network device of claim **1**, wherein the first response comprises one or more of a probe response, an authentication response, and an association response.

5. The network device of claim **1**, wherein the disconnection request comprises one or more of a de-authentication request and a disassociation request.

6. The network device of claim **1**, wherein the selected MAC address is used to emulate a client device in the wireless local area network.

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